Radar Systems and
Remote Sensing Laboratory

AR TECHNIQUE APPLIED TO ANALYZE THE MODULATION OF OCEAN WAVES

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Modulation between radar backscattered power, surface slope, and surface elevation may be viewed for individual ocean wave frequencies using autoregressive (AR) parametric spectral estimator. We analyze data recorded at Duck Pier during December 1995. Our technique based on autoregression is a powerful tool that may help gain understanding of the modulations due to ocean waves.

I. *Introduction*

We apply autoregressive (AR) modeling of ocean waves to observe the relations between surface elevation, surface slope, and the microwave signature of ocean waves with periods between 1.56 to 12.5 sec. (0.08 to 0.64 Hz). We expand the approach based on the autoregressive parametric spectral estimator [Haimov, et al., 1993] to include surface slopes. We gathered data at Duck Pier [Legarsky, et al., 1996] in December 1995 of surface elevation, surface slope, and the microwave signature (radar backscattered power). We use our experimental

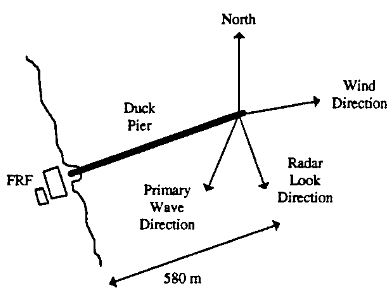

Figure 1 Duck Pier scene for Run_1 on 12/09/1995

data in the AR model resulting in the observance of the relations between surface elevation, surface slope, and backscattered power.

II. *Approach*

We choose to analyze the long ocean waves with frequencies in the range 0.08 to 0.64 Hz. We break this range into three bands: 1) 0.08 to 0.16 Hz containing the primary long wave, 2) 0.16 to 0.32 Hz covering the second harmonic of the primary long wave, and 3) 0.32 to 0.64 Hz covering the third harmonic of the primary long

Figure 2 Ocean spectra bands used for AR analysis

wave as shown in figure 2. For each band, we find the individual wave cycles and determine the phase of each data point of each cycle. The phase information allows us to average individual cycles on a phase basis resulting in a reconstruction of the ocean wave, slope along the wave, and power along the wave. Filtered data of 1 Hz in conjunction with the phase information in the *band* result in a view of the modulation occurring at ocean wave frequencies in the band.

III. *Results*

We reconstructed the ocean waveheight, radar backscattered power, and surface slope as shown in figures 3, 5, and 7 for the data run_1. We show the ocean wave shape for different frequencies exhibits a similar form. The radar backscatter and the surface slope across the ocean wave phase matches well for band 1 and 2. Band 3 shows a different behavior from the bands 1 and 2. The power vs. slope relation fits reasonably well with a straight line for bands 1 and 2. The band 3 power vs. slope relation shows some trend but not as distinct as bands 1 and 2. As a result of the AR technique, relations between waveheight, backscattered power, and surface may be found over bands of the ocean wave spectra.

IV. *Conclusion*

We find the AR technique to be a viable means to view the modulation of slope, power, and waveheight over several bands of the ocean wave spectra to see how they relate.

V. *References*

Haimov, S., V. Hesany, and R.K. Moore, "Autoregressive modeling for ocean wave—radar modulation transfer function," *J. Geophys. Res.*, vol. 98, pp. 8517-8529, 1993.

Legarsky, J.J. and R.K. Moore, "1995 test of the vector slope gauge at Duck, North Carolina," RSL Technical Report 8621-8 and 10530-1, The University of Kansas, May 1996.

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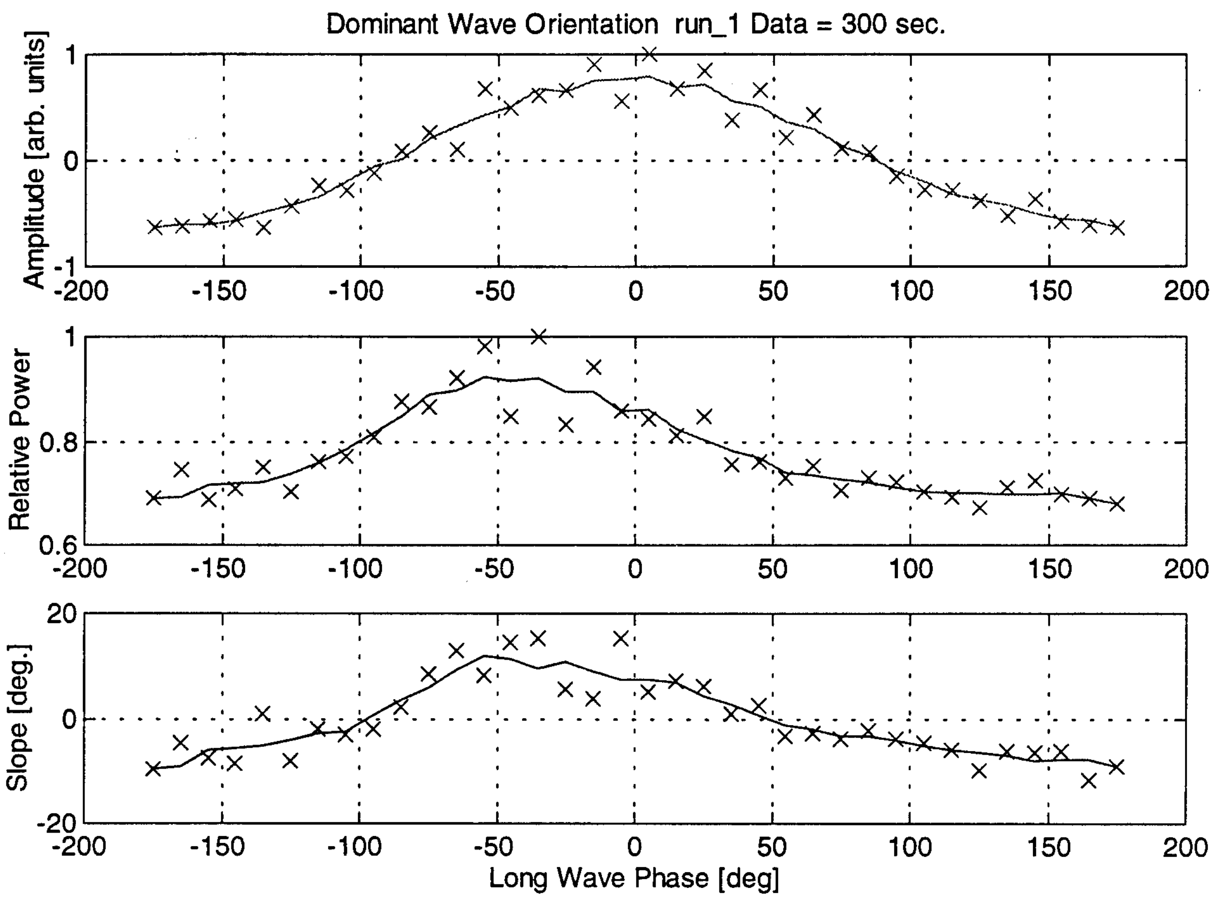
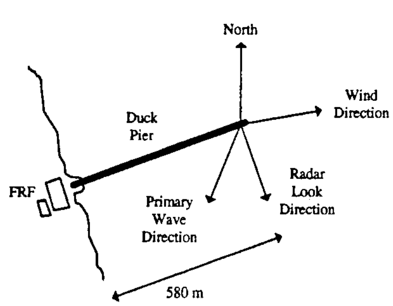


Figure 3 AR result

VSG Ka-band data set run_1 of length 5 min. collected on 12/09/1995.
Wind Speed is 4.5 m/s. Wind Direction is 258°. Primary Wave Direction is 29°.
Radar look direction is 160°. Angle of incidence is 61°. Polarization is VV.
AR time window is 6.25 to 12.5 sec. (**0.08 to 0.16 Hz ocean waves**). AR order is 8.



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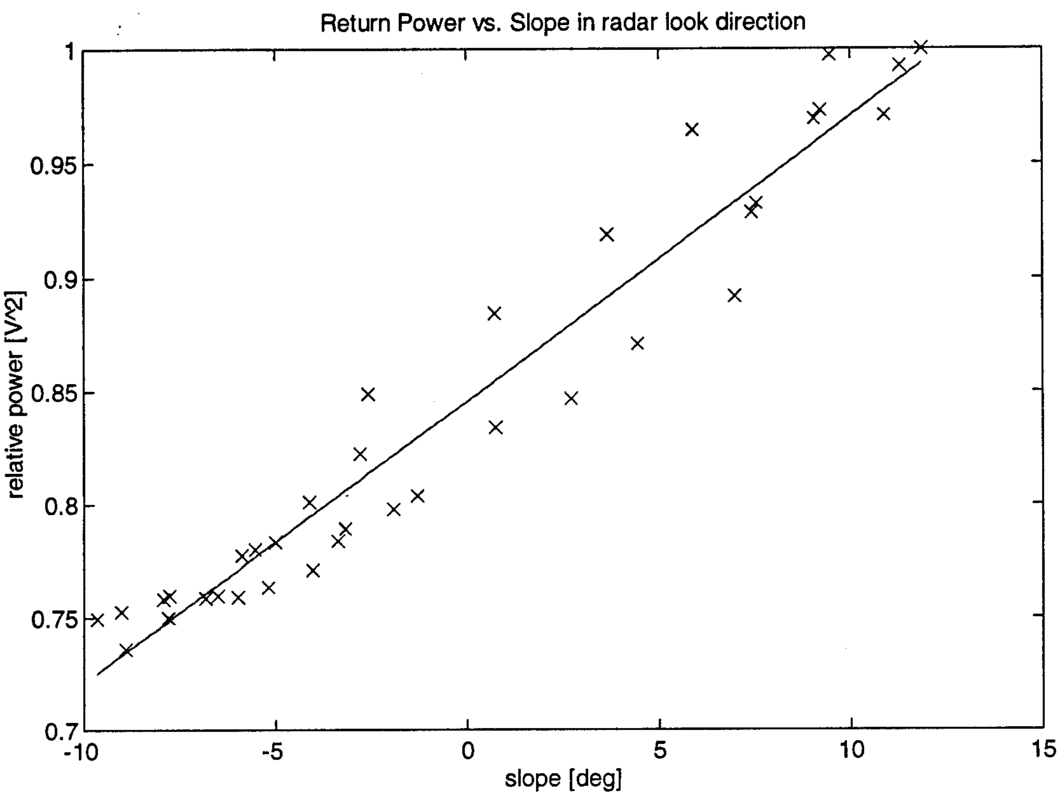

Figure 4 Power vs. Slope using AR result

VSG Ka-band data set run_1 of length 5 min. collected on 12/09/1995.
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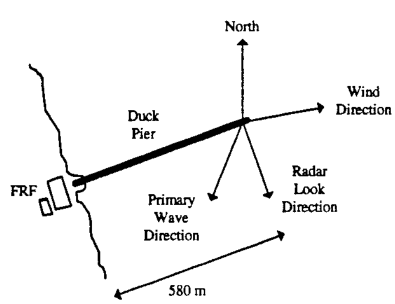


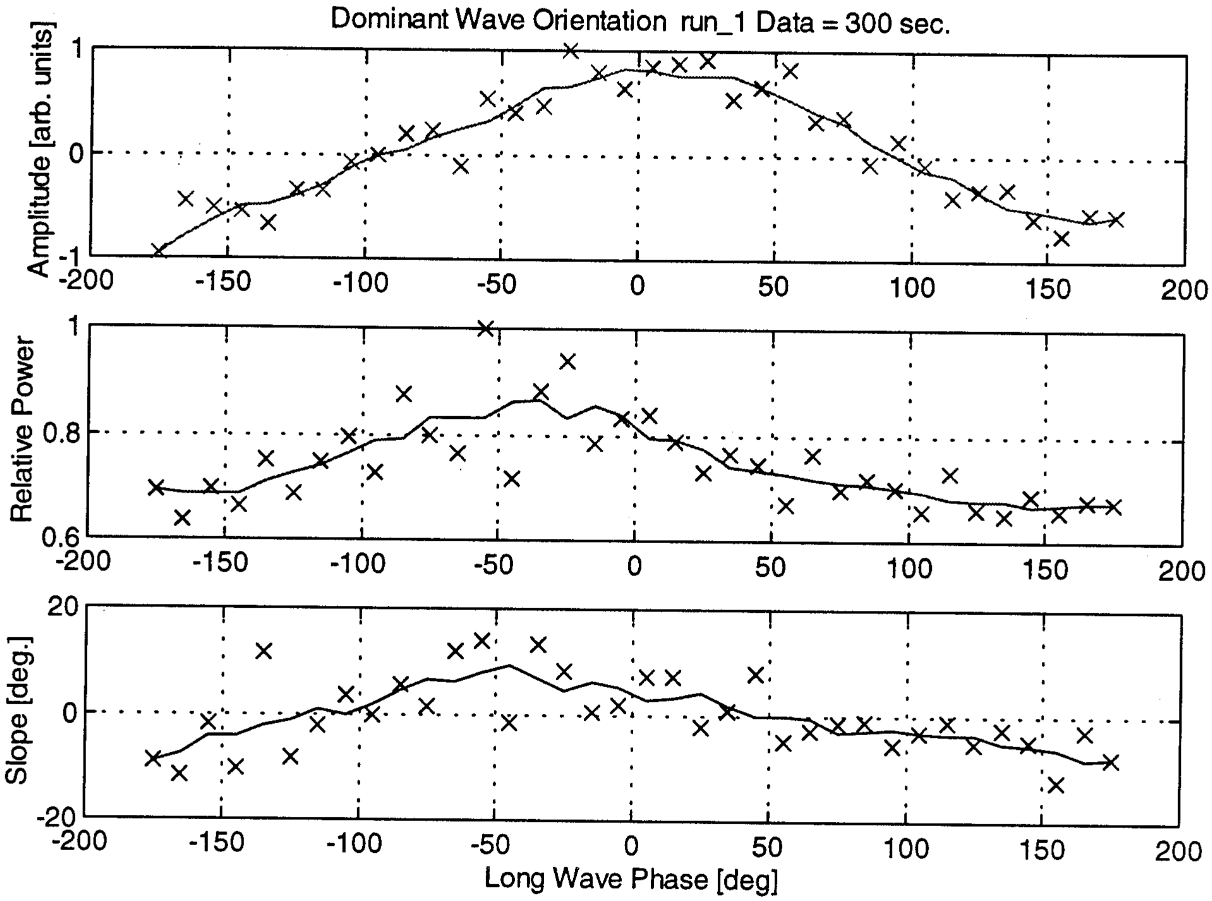
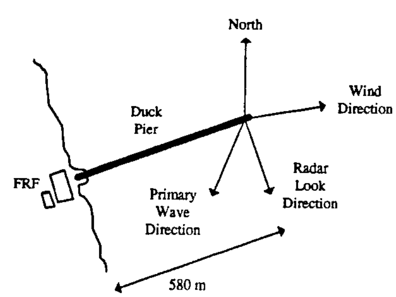


Figure 5 AR result

VSG Ka-band data set run_1 of length 5 min. collected on 12/09/1995.
Wind Speed is 4.5 m/s. Wind Direction is 258°. Primary Wave Direction is 29°.
Radar look direction is 160°. Angle of incidence is 61°. Polarization is VV.
AR time window is 3.12 to 6.25 sec. (**0.16 to 0.32 Hz ocean waves**). AR order is 8.



AR technique applied to analyze the modulation of ocean waves

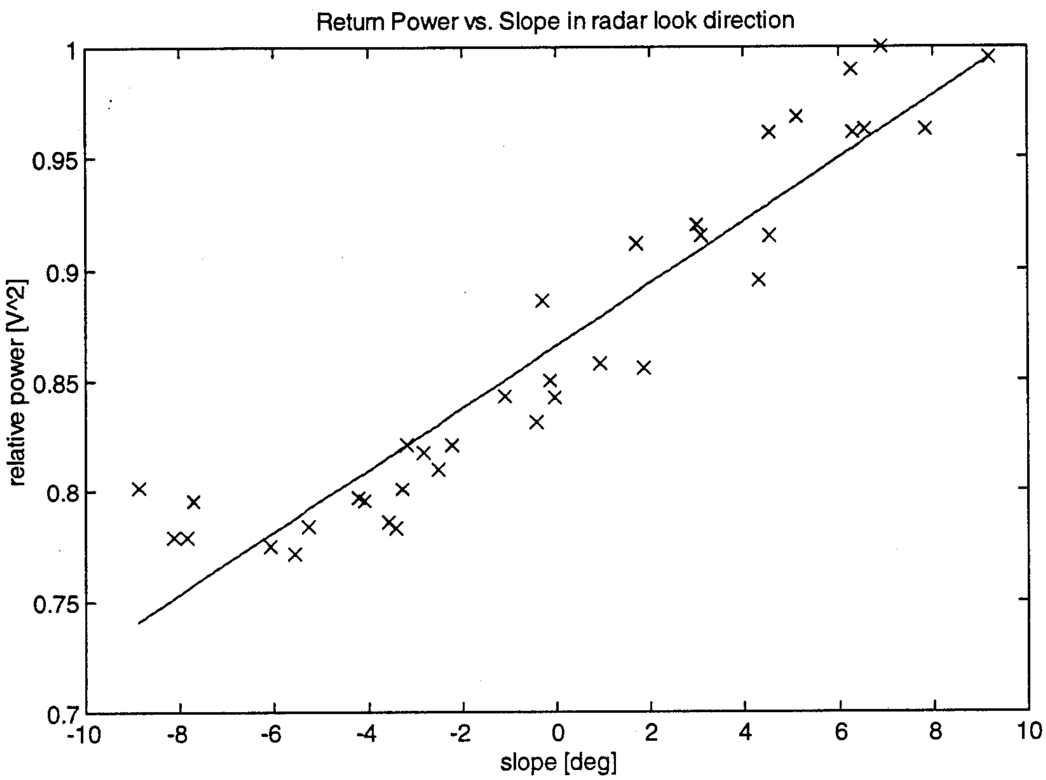


Figure 6 Power vs. Slope using AR result

VSG Ka-band data set run_1 of length 5 min. collected on 12/09/1995.
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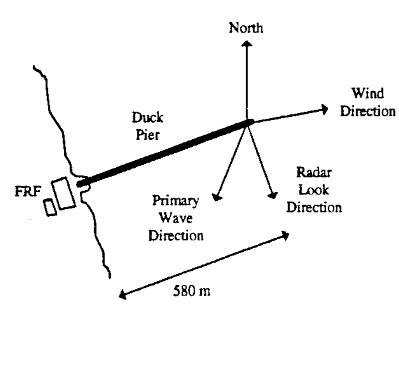


AR technique applied to analyze the modulation of ocean waves

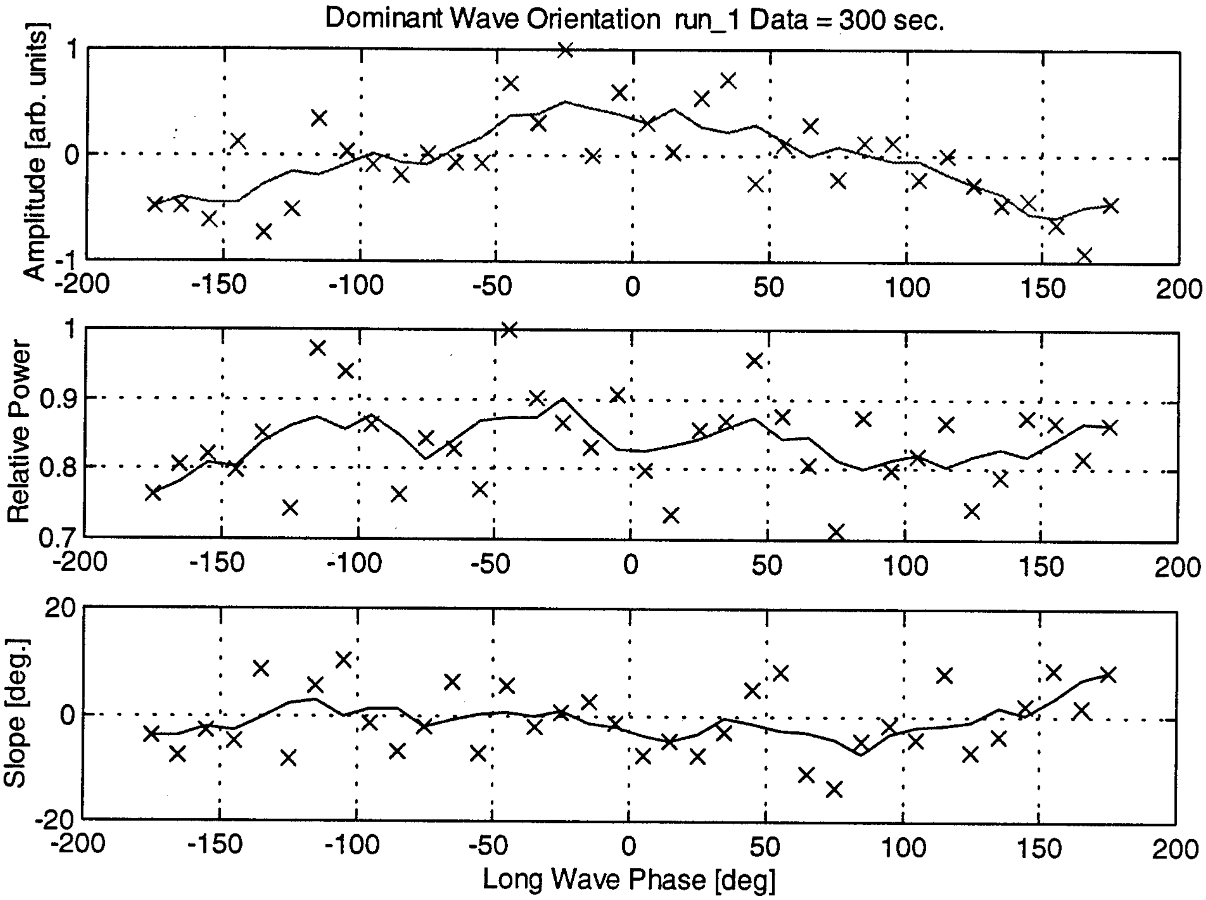
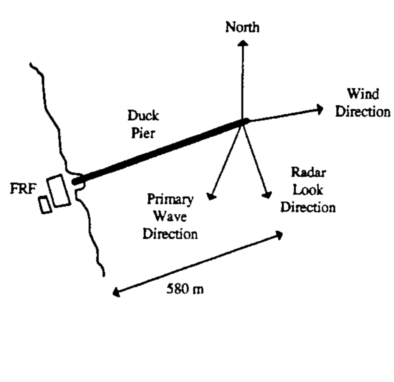


Figure 7 AR result

VSG Ka-band data set run_1 of length 5 min. collected on 12/09/1995.
Wind Speed is 4.5 m/s. Wind Direction is 258°. Primary Wave Direction is 29°.
Radar look direction is 160°. Angle of incidence is 61°. Polarization is VV.
AR time window is 1.56 to 3.12 sec. (**0.32 to 0.64 Hz ocean waves**). AR order is 4.



AR technique applied to analyze the modulation of ocean waves

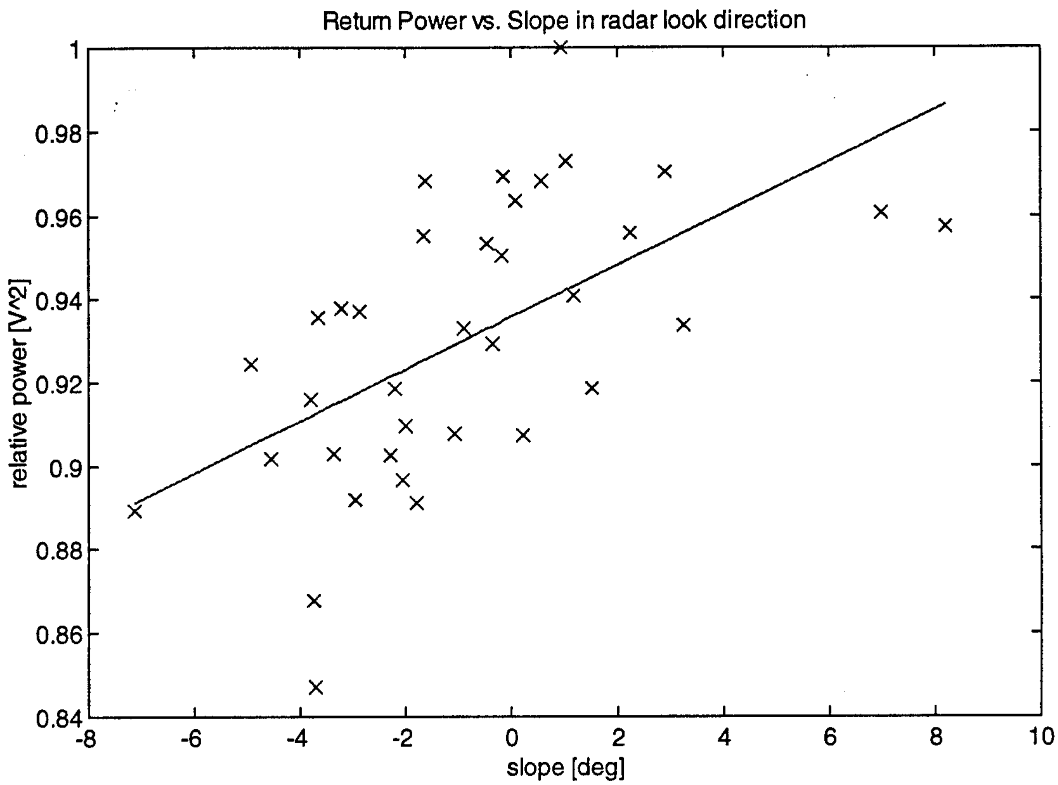


Figure 8 Power vs. Slope using AR result

VSG Ka-band data set run_1 of length 5 min. collected on 12/09/1995.
Wind Speed is 4.5 m/s. Wind Direction is 258°. Primary Wave Direction is 29°.
Radar look direction is 160°. Angle of incidence is 61°. Polarization is VV.
AR time window is 1.56 to 3.12 sec. (**0.32 to 0.64 Hz ocean waves**). AR order is 4.